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Original Article

Mtoto Wetu Growth and Temperature Monitoring System for Tanzania Child Healthcare Clinics

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ABSTRACT

In most government maternal and child health (MCH) clinics in sub-Saharan countries caregivers rely on manual methods for data acquisition, storage, and analysis, leading to challenges such as errors, inefficiencies, and limited accessibility. Recognising the transformative potential of digital technology, this design aims to innovate the child growth monitoring paradigm by introducing a comprehensive Digitized Child Growth Monitoring System. The "Mtoto Wetu Growth and Temperature Monitoring System" is a comprehensive framework designed to monitor and assess the growth and temperature patterns of infants and young children on a monthly basis. This system integrates various components, including anthropometric measurements, temperature monitoring, immunisation schedule, automated growth chart generation, and parental, caregiver, and health care professionals' involvement, to provide a holistic approach to child health monitoring. Implemented with standardised protocols, training sessions, and robust data management systems, the monitoring system aims to facilitate early detection of growth abnormalities, and health concerns. By promoting early intervention, preventive care measures, parental empowerment, and continuity of care, the Mtoto Wetu system strives to optimise health outcomes, foster parental engagement, and promote health equity among children. The system was able to provide results with a small amount of error compared to the standard weighing machines, tap measure and digital thermometer.

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INTRODUCTION

A child growth and temperature monthly monitoring system is a comprehensive framework designed to track and assess the health and development of infants and young children regularly (Radgohar et al., 2020; Utomo et al., 2020; Yap et al., 2018; Prabhakar et al., 2020; Joseph et al., 2018; Fakhri et al., 2020). This system incorporates various indicators, measurements, and assessments to ensure the holistic monitoring of a child's growth, nutritional status, and overall well-being (Requejo et al., 2022; Sentongo, 2019). Regular weight, height/length, and head circumference measurements are fundamental to assessing physical growth and nutritional status. These measurements help identify growth patterns, detect deviations from the norm, and guide appropriate interventions (Madden & Smith, 2016; Scheffler et al., 2017; Eze et al., 2017). Regular monitoring of body temperature is essential for detecting fever, which may indicate underlying infections or illnesses (Raj & Lodha, 2013). Temperature measurements provide valuable information about a child's health status and can prompt timely medical attention if necessary (Garcia-Souto & Dabnichki, 2018; Geddes, 2020).

The existing healthcare infrastructure, while dedicated to addressing these challenges, often encounters limitations in data accuracy, accessibility, and timeliness (Gladstone et al., 2021). At most Tanzanian government maternal and child health (MCH) clinics, caregivers manually register a child, measure their height, and weight, and then plot the measurements on growth charts for interpretation. These scales are not as accurate as they could be, so they often give wrong measurements (Wedha et al., 2022). Available types of scales for measuring a child's weight include spring scales, hanging scales, beam balance scales, and digital scales. Each child over the age of 24 months has their height measured using a length measurement board with a movable headpiece, and children under 24 months have their boards placed on a flat, stable surface (Semali et al., 2015). There is a need for comprehensive child growth monitoring systems that can be accessed online, with the former focusing on nutritional status analysis and the latter on growth and development monitoring (Utomo et al., 2020; Siswati et al., 2022). Over one-third of fatalities among children aged five and below can be attributed to malaria disease in sub-Saharan Africa, including Tanzania (Sarfo et al., 2023). Therefore, integrating the smart weighing scale with a temperature-sensing mechanism is important because it is one of the symptoms of malaria. Measuring temperature every time a child visits is necessary, which is one of the malaria symptoms (Kabaghe et al., 2018).

Various smart child weighing scales that use advanced technology to offer comprehensive health and growth insights, enhancing the convenience for parents and healthcare professionals to monitor their child's health have been developed. Parents can track their babies' weight and height through the mobile app. The mobile app tools automatically measure a baby's height and weight just using a traditional weighing scale and a custom baby blanket (Fletcher et al., 2017). The Mtoto Wetu Growth and Temperature Monitoring System (MWGTMS) encompasses the comprehensive digitisation of the child growth monitoring process, addressing challenges related to data acquisition, analysis, sharing, and storage arising from the current use of paper cards. Key components include the development of a user-friendly digital interface for accurate and standardised data collection, the establishment of a secure centralised database for efficient storage, real-time monitoring capabilities, and automated data analysis algorithms. The scope aims to enhance the accuracy and accessibility of child growth data, ultimately improving the quality of paediatric healthcare interventions on a global scale.

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The paper's organisation follows. Section 2 discusses child anthropometric and body temperature measurement methods. Section 3 describes the child growth and temperature monitoring system design approach. Section 4 describes the system's design and performance. Section 5 discusses and concludes the results.

RELATED WORK

Electronic weighing scales are widely used in various fields such as agriculture, industry, health and commerce due to their accuracy, reliability, and ease of use. In recent years, there has been a significant increase in the development of electronic weighing scales, and many researchers have conducted studies to improve their performance and functionality. Ramkumar et al., (2021) proposed a smart weighing scale integrated into a smartphone application using IoT, to measure the weight of Areca nuts in real-time and send the data to the application via the ESP8266 Wi-Fi module. The system's Android application provided the measured weight of Areca nuts to the farm owner without requiring his presence, and it delivered income details by supplying information on profit or loss through the application. Nanak et al (2022) presented a method for measuring height and weight using ultrasonic, loadcell sensors, and NodeMCU ESP8266 as data processors. The system utilised an LCD and a smartphone to display the measured height and weight data and emitted sound through the speaker. The sound from the speaker enabled people with disabilities to become aware of their body condition. The limitation of that system provided an error of about 4.4% for height measurement (Nanak et al., 2022). The design of electronic weighing scales can also be useful in health care centres to track children's weight and can be integrated with height measurement. The Children Growth Monitoring System (CGMS) is intended to collect the parameters (height, weight, and BMI) measured by the hardware device and the Growth Meter (GM) software built on the Android platform (encompassing both smartphones and tablets) (Vaidya et al., 2014).

The Automatic Height and Weight Measurement Integrated Database System was developed to measure height and weight and produce integrated information in a database. The designed system simplifies data recapping, archiving, and storage for school-aged 5 to 15-year-old child growth evaluation and monitoring, providing a reference for future follow-up (Rahmalisa & Yulisman, 2021). Ulyanida et al (2022) developed an automatic weight and height measurement instrument that detects height using an Ultrasonic Sensor, and weight using four Wheatstone bridge load cells connected to the HX711 module. Results were displayed on an LCD and an application interface was created with Microsoft Visual Studio, demonstrating the instrument's efficiency and accessibility in data collection. Previous studies succeeded in measuring the height and weight of children aged 2 and above, but they missed the temperature parameter, which can be useful for sub-Saharan countries. This study created a system that measures weight, height, and temperature, displays the data on an LCD, a smartphone, or a computer, and stores the data for later use.

METHODS AND ANALYSIS

Mtoto Wetu Growth and Temperature Monitoring System (MWGTMS) is an integrated system designed to positively enhance mother-child health clinics. This is by digitizing the child's data on vaccination, health, and growth. The system will comprise two main parts: the hardware (electronic scale) and the software part.

The electronic scale (hardware)

The electronic scale contains sensors that collect information, a control unit, a database, RFID, a Network module, a Display unit, and a power supply. For measuring the required information, such as Temperature, weight, and height then calculating the BMI and giving out the results. Figure 1 shows the block diagram of mtoto wetu electronic scale.

In the MWGMS, the sensing unit has sensors for sensing the height, weight, and temperature of a child. Three ultrasonic sensors (HC-SRO4) are

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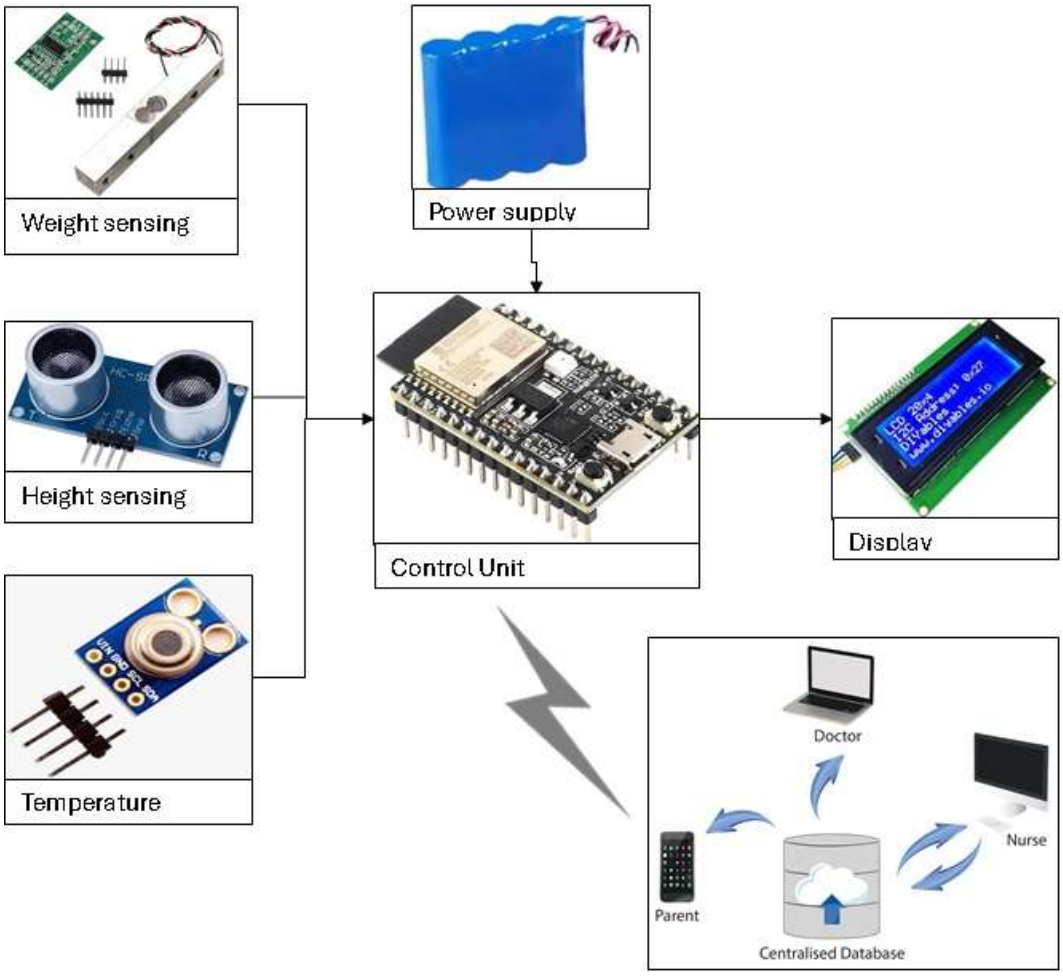
used to measure the height by transmitting the sound wave and receiving the echoes after they have been reflected from the object. It calculates the distance by multiplying the time taken to receive the returned sound by the speed of the sound [16,27]. One ultrasonic sensor is used for measuring the height of a standing child, while two sensors are used for a lying-down child. The system uses a load cell and HX711 amplifier to measure the weight of a child, while the temperature sensor (MLX 90164) measures the child's body temperature to detect whether a child has a fever or not. The control unit (ESP 32 Devkit) controls all the operations by coordinating the input and output modules. Any condition detected by the sensor and measurements taken will be determined by the control unit, and the output will be displayed by the display and sent automatically to the website through the internet. To establish the connection, the electronic scale will turn on a mobile hotspot to allow the user to set the wi-fi credentials of the local LAN wi-fi hotspot or any hotspot of choice. The user (a nurse or local doctor) will connect to the electronic scale network, and then surf on the browser's IP address.

Figure 1. Block diagram of MWGMS.



After surfing, the user will log in by entering the credentials, then submit. Then the connection will be established, and the display will show the statement "Connected," hence enabling full operation of the system. The push button is used to reset the process. The circuit diagram of the MWGM system is shown in Figure 2.

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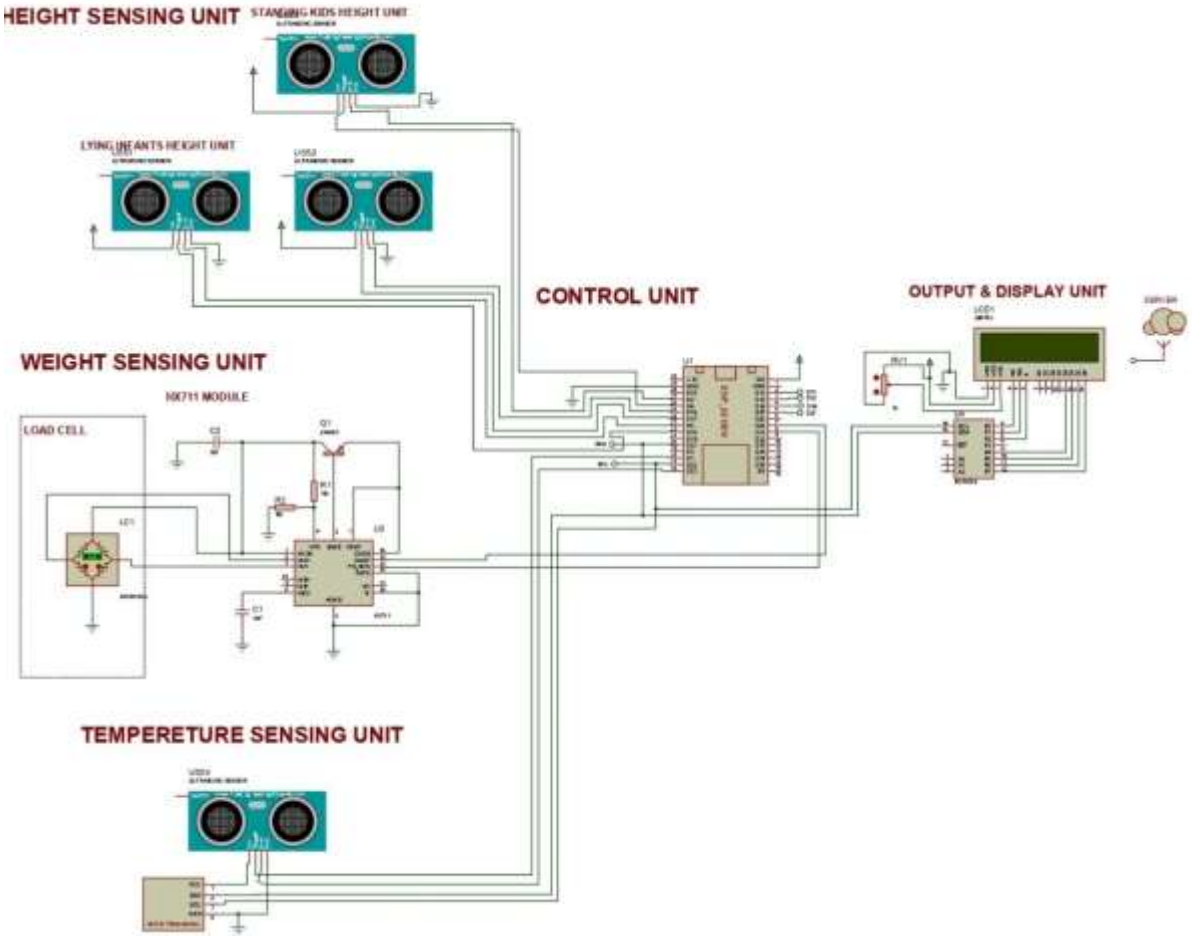
Figure 2. MWGTM system schematic circuit diagram



Anthropometric scale

The structure of the MWGM system anthropometric scale involves components like a stable platform where a child can lie down, sit, and stand comfortably. The platform includes a load cell sensor to detect a child's weight, which supports different weight capacities and provides accurate readings. The scale has a light plastic tray for infants to lie down and measure weight, height, and temperature. The system also features two adjustable boards equipped with two ultrasonic sensors to measure the heights of children under two years old, and a vertical adjustable rod with one ultrasonic sensor to accommodate children over two years old. A temperature sensor attached to a flexible cable is integrated into a system to measure the child's body temperature. The digital display and interface equipped in the system provide easy-to-read measurements and allow healthcare professionals to access the collected data. The structure of the MWGM system is shown in Figure 3.

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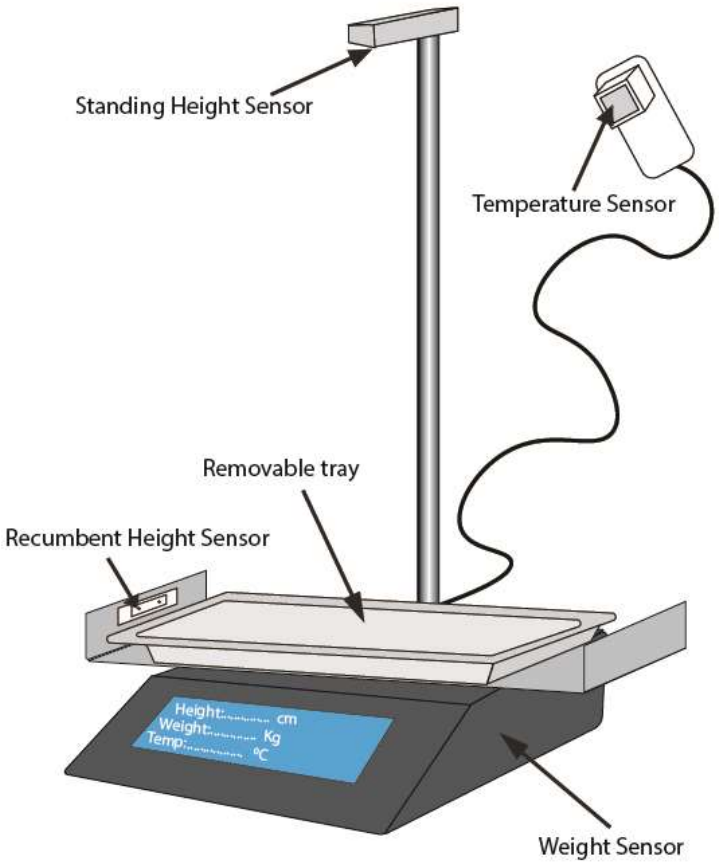
Figure 3. MWGTM system structure



Software part structure

The software part structure of the MWGTM system consists of a user interface, database, and backend server. The user interface allows the healthcare nurse to enter children's personal data and receive data from the electronic scale and store the data to the respective child in the database. The backend server processes the data, performs calculations to determine growth patterns and tabulates them to simplify interpretation. This is the heart of the system since it performs and enhances various activities which are: data access management (DAM) and user access management (UAM).

Data Access Management

Data Access Management involves the access to manipulate data by allowing various processes such as data updating, deletion, addition, and analysis.

User Access Management

User Access Management involves user registration and privileges, defining the data accessible to each user. The system had the following users: Parents (Mother and father), Nurses, Resident Doctors, District Doctors, Regional Doctors, National Doctors, and System Administrator.

Parents

Parents include the mother and/or father or guardian of the child. Each registered parent will be able to access the following: The monthly report of his or her child or children, the annual report of his or her child or children, the growth chart, and any recorded information on his or her child or children use any designed tool to analyse his or her child's information.

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Nurse

Nurses included all those responsible for the mother-child care program. Each registered nurse, based on the hospital they worked in, was able to access the following: monthly reports of children registered at the respective hospital, annual reports of children registered at the respective hospital, growth charts and any recorded information on children registered at the respective hospital, and use any designed tools to analyse the information of children registered at the respective hospital. The nurse deals with the transfer process when a child is required to transfer from one hospital to another hospital, makes clear the days of the child clinic and shares the information with all responsible persons e.g., parents, doctors if any, provide any recommendations to the child's reports, update child information where required, register the parents, and register the children.

Resident Doctor

Resident doctors include all resident doctors in the respective hospital responsible for the mother-child care program. Each resident doctor accesses the following: The Monthly reports of children registered in the respective hospital, Annual reports of children registered in the respective hospital, Growth chart, and any recorded information on children registered in the respective hospital, Use any designed tool to analyse information of the children registered in the respective hospital, Perform data analysis and produce a comprehensive report on his/her hospital, and Provide any recommendations to the child's reports.

District doctor

District doctors included all administrative district doctors. Each district doctor was registered and had access to the following: monthly reports of children registered in the respective district, annual reports of children registered in the respective district, growth charts and any recorded information on children in the respective district, tools for analysing the information of children registered in the district, the ability to provide recommendations on a child's or hospital's reports, and the capability to perform hospital-wise data analysis and produce a comprehensive report on their district.

Regional doctor

Regional doctors included all administrative regional doctors. Each regional doctor was registered and had access to the following: monthly reports of children registered in the respective region, annual reports of children registered in the respective region, growth charts and any recorded information on children in the region, tools for analysing the information of children registered in the region, the ability to provide recommendations on a child's, hospitals, or district's reports, and the capability to perform hospital-wise or district-wise data analysis and produce a comprehensive report on their region.

National doctor

The national doctor includes all administrative national doctors. Each registered national doctor had to access the following: Monthly reports of children registered in the nation, annual reports of children registered in the nation, growth charts and any recorded information on children registered in the nation, use any designed tool to analyse information of the children registered in the nation, provide any recommendations to the child's, hospital, district or regional reports, and perform data analysis hospital-wise, district-wise or regional-wise and produce a comprehensive report on his/her region.

System administrator

The system administrator is responsible for registering new users (national doctor, regional doctor, district doctor, resident doctor, or nurse), removing registered users, updating information on registered users, and assisting registered users with the usefulness of the system.

RESULTS AND DISCUSSIONS

The weight measurement was done using four standard solid brass weighing stones with 0.25,

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0.5, 1 and 2 Kg the measurements were conducted on different days and results are shown in Table 1. Assuming that any measurement with a weight below 1 kg is considered an error and will not be sent to the database, the scale can measure up to 20 kg because that is the standard weight for the child who is supposed to attend.

Table 1: Measurement results comparison

S/N	Standard value			Measured value			Error		
	Weight (Kg)	Height (cm)	Temperature (°C)	Weight (Kg)	Height (cm)	Temperature (°C)	Weight (Kg)	Height (cm)	Temperature (°C)
1.	0.5	4.3	22.7	0.497	4.3	22.84	0.003	0	-0.14
2.	1	5.5	28.5	0.998	5.5	25.57	0.002	0	-0.07
3.	1.5	6	36.5	1.495	6.04	35.42	0.005	-0.04	0.08
4.	2	10	36.9	1.992	10.05	36.85	0.008	-0.05	0.05
5.	3	30	37.2	2.990	30.05	37.20	0.01	-0.05	0
6.	3.5	50	36.7	3.492	50.07	36.72	0.008	-0.07	-0.02

The error was the difference between the standard, measured value using an existing standard device and the reading value from the Mtoto Wetu weighing machine. It was discovered that the relative error fell between 0.00 and 0.01 kg for weight measurement which is acceptable accuracy for weight measurement (Foote et al, 2009). Again, the maximum measurement error for temperature is 0.14℃ which is a much smaller acceptable error which is 0.5℃ (Davies et al, 1986). While the measurement error for the height of the developed instrument is much less than one which is acceptable in the infant height measurement.

In web applications, users are required to log in MWGTM system. The administrator will create the user interface for nurses and all required doctors. The nurse will login using the login page shown in Figure 4 and register children and their parents or guardians' information as shown in Figure 5. The nurse home page menu shown in Figure 6 consists of data which includes vaccine data entered by the nurse, weight, height, and temperature from the electronic scale as well as the general table.

Figure 4. User login page

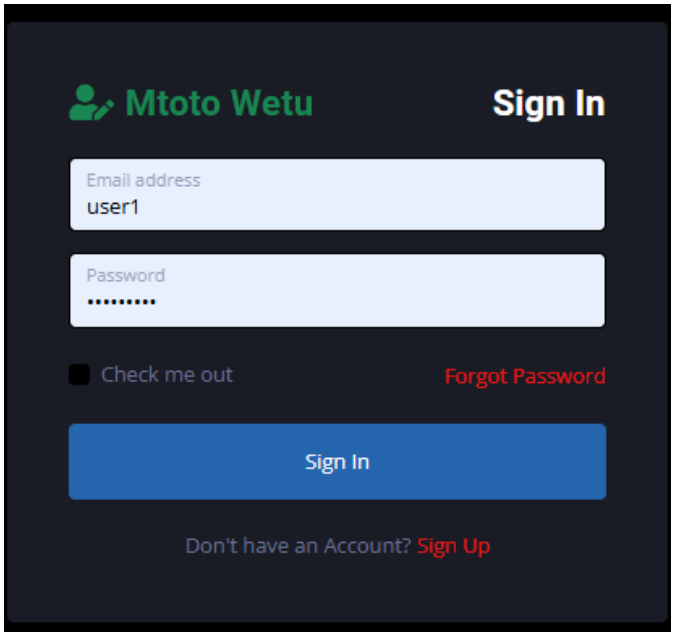

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Figure 5. Registration interface

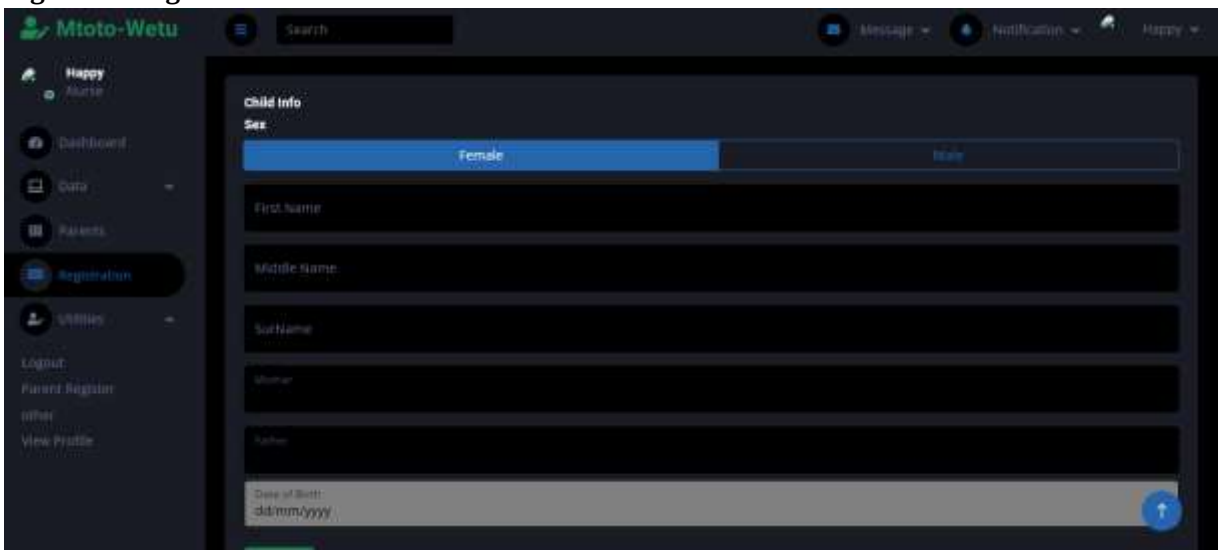
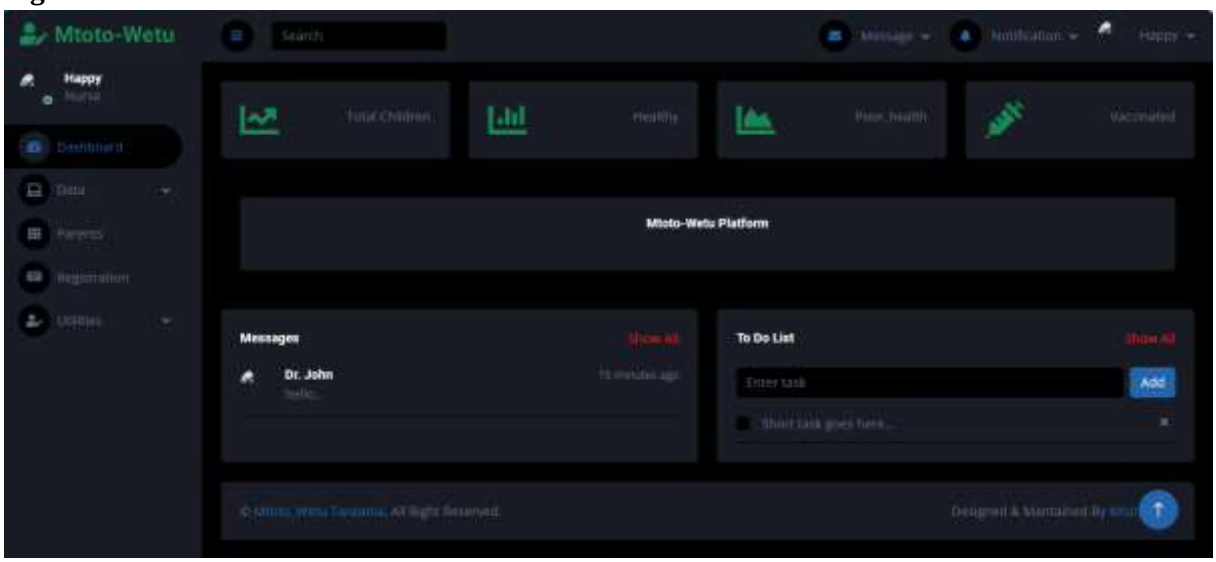


Figure 6. Mtoto Wetu Nurse dashboard



The measured data in real-time from weight, height and temperature sensors was displayed on the scale display but also sent to the webserver to be transmitted over the Internet, saved, and displayed on a webpage for distant viewers. The generated child's growth curve is illustrated in Figure 7, illustrating weight against the child's age table indicating the height, temperature and weight are displayed to show the numerical number of the measured values.

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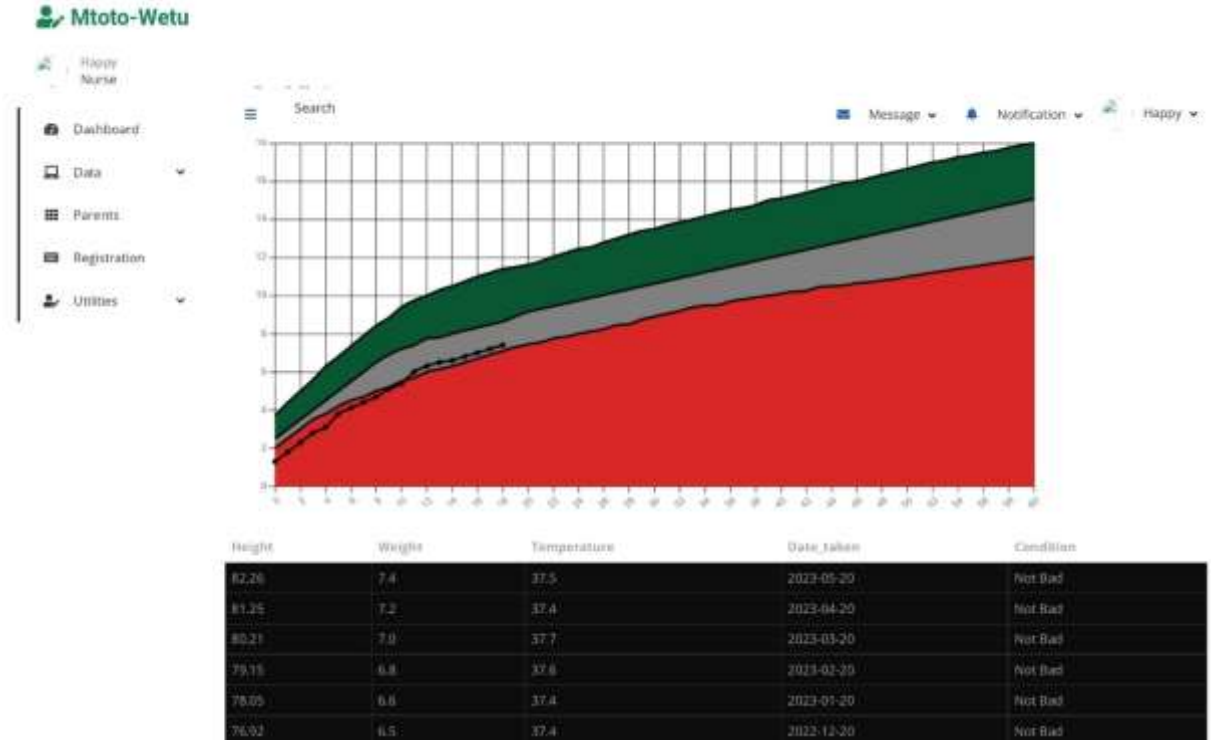
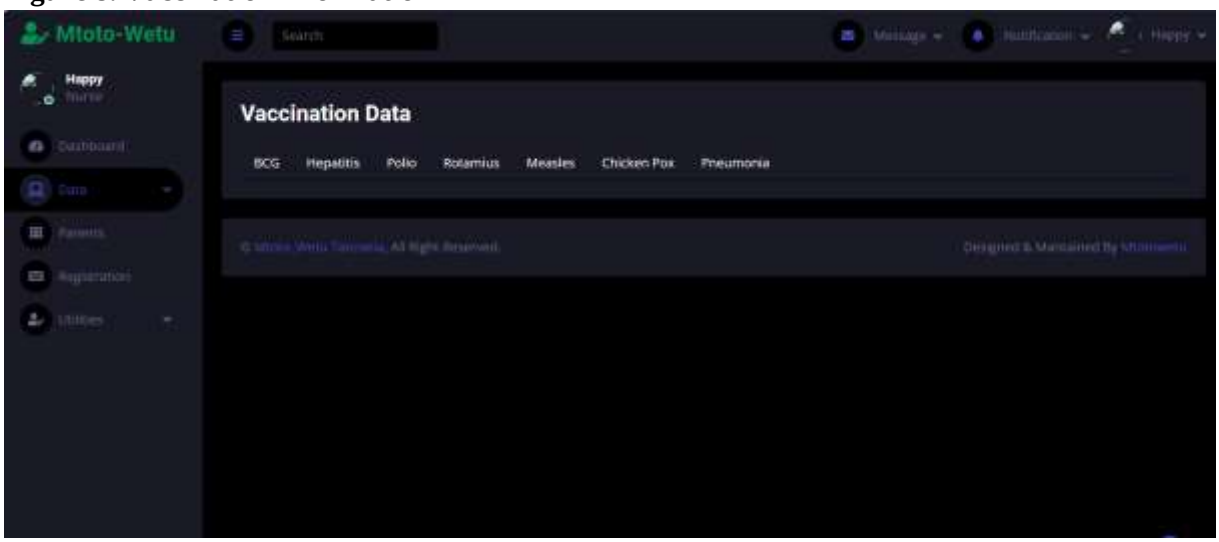
Figure 7. Weight growth chart, height, and temperature data



The history of vaccination information is shown in Figure 8 showing all kinds of vaccinations offered to children in Tanzania. Since the scale is integrated with the web server, doctors and researchers can use data from this system to monitor children's nutrition in Tanzania

Figure 8. Vaccination information



An example of a district summary report for healthiness and unhealthy children is illustrated in Figure 9.

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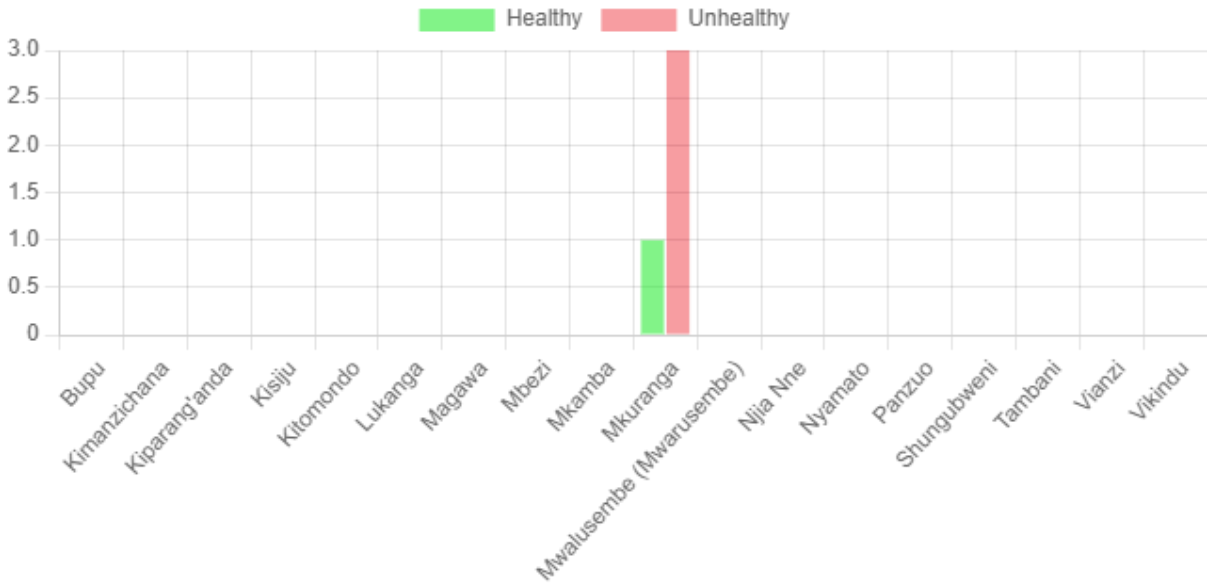
Figure 9. Example of children's health status in Mkuranga district.



Conclusion

The use of the Internet of Things (IoT) and electronics can reduce or eliminate the use of hard cards in healthcare centres for monitoring children's growth in Tanzania. The Mtoto Wetu growth monitoring system was designed, developed, and implemented as a prototype to enable healthcare centres, researchers, and government officials to monitor children's growth and improve child health services. The MWGTM anthropometric scale prototype offers adequate accuracy for weight, height, and temperature, with relative errors of less than 0.01kg, 0.07 cm, and 0.14℃. Children's growth indicators Weight and height information were taken via the load cell and ultrasonic sensors, respectively, and saved in the database to minimise the issue of losing the child's background information.

The research recommends mtoto wetu growth monitoring system be used by healthcare centres in Tanzania.

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